Proceedings of the Waste Safe 2023 – 8th International Conference on Integrated Solid Waste and Faecal Sludge Management
25-26 February 2023, Khulna, Bangladesh

COMPOSTING: AN EFFECTIVE BIOLOGICAL SOLID WASTE TREATMENT PROCESS

Q. Hamidul Bari

Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna-9203, Bangladesh

ABSTRACT

The present waste management hierarchy emphasizes reduce, reuse, recycle, recover and residue. After reducing and reusing the materials, there will be substantial amounts of solid waste containing recyclable and non-recyclable portions to be managed. A large portion of this waste is biodegradable. The organic biodegradable portion could be managed either by biological treatment, or disposal in landfills. Biological treatment offers a cost-effective solution for biodegradable organic wastes. In practice, the main biological process applied for solid wastes is composting. In this paper, a review of the historical development of the composting process in different countries, different technological aspects and its further usages are discussed. It can be noted that the main composting technologies are forced aeration, and mechanical turnover in a reactor or in a windrow composting pile. The reactors could be static or slowly rotating and the windrow could be formed in an open field or inside a shelter. Furthermore, the process could be batch or continuous.

***Keywords**: solid waste, biodegradable portion, waste recovery, bacteria, temperature, aeration.*

INTRODUCTION

Future living standards and the quality of the environment essentially depend on the management policies for solid wastes together with the management of other emissions. The increasing rate of solid waste generation from different sources, limited landfill space and more stringent environmental regulations for new landfill sites and incinerators have increased the waste disposal charges. Therefore, municipalities and local governments are under heavy pressure to find sustainable and cost-effective waste management policies. The present waste management hierarchy emphasizes reduce, reuse, recycle, recover and residue. After reducing and reusing the materials, there will be substantial amounts of solid waste containing recyclable and non-recyclable portions to be managed. A large portion of this waste is biodegradable; for example, source-separated organic solid wastes including household refuse, market wastes and agricultural wastes or sewage sludge. The organic biodegradable portion could be managed either by biological treatment, or disposal in landfills.

Usually, the organic wastes which are disposed of directly with other wastes in landfills create further long-term problems by producing secondary pollutants including methane, ammonia, hydrogen sulfide, volatile organic compounds and leachate through anaerobic decomposition. These pollutants are entering either the atmosphere as gases or the groundwater as leachate. Hence new landfills require separate units for long-term leachate/gas collection, treatment and monitoring systems. However, biological treatment offers a cost-effective solution for biodegradable organic wastes. In practice, the main biological

ISBN: 978-984-35-4034-8

process applied for solid wastes is composting (Haug 1993, Tchobanoglous et al. 1993). This is a sustainable waste management technique in developing countries (Taiwo 2011, Ishola and Ishola 2019). Composting is the biological degradation of highly concentrated biodegradable organic wastes in the presence of oxygen to carbon dioxide and water, whereby the biologically generated waste heat is sufficient to raise the temperature of the composting mass to the thermophilic range. The final product of composting is a stable humus-like material known as compost.

Small-scale composting of night soil and other organic wastes has been used successfully in the agriculture of different countries of the world since times immemorial. The Indore Process in India conducted by Sir Albert Howard from 1924 to 1931 represented the first organized plant for composting in the modern era. The first full-scale refuse composting facility in Europe was established in the Netherlands in 1932 which was a modification of the Indore process. In the 1940s, several mechanical composting systems were introduced in Europe. Composting activities in Australia, Japan, New Zealand and the United States during the 1950s are also reported. Currently, in Europe, the entire organic portion of municipal solid waste is either fermented or composted. Many large cities in Asia are planning to erect or improve existing municipal waste composting. Sewage sludge composting has also become very common since the 1970s in the USA.

HISTORICAL OVERVIEW

The British agronomist Sir Albert Howard conducted studies and experiments, between the years 1924 to 1931, in India that established the basic principles of composting (Spellman 1997). His process is known as Indore Process. The Indore Process represented the first organized plan for composting in the modern era (Haug 1993). That process was usually conducted in pits or piles of 9 x 4 x 0.9 m deep or high. Preparation of the compost pile consisted of alternate thick and thin layers of vegetable waste (152 mm) and animal manure (51 mm), respectively. The layering was repeated until a height of 0.9 m was reached. The pile was turned after 16, 30 and 60 days with intermittent re-moisturizing and the whole process was completed after 90 days.

The first full-scale refuse composting facility in Europe was established in the Netherlands in 1932 and was a modification of the Indore process (Epstein 1997). In the 1940s, several mechanical composting systems were introduced in Europe (Kuter 1995). Composting activities in Australia, Japan, New Zealand and the United States during the 1950s are also reported (Snell 1957, Mantell 1975). However, during that early stage of composting most large-scale plants were established in Europe. After 50 to 80 years, several early researches including 'Influence of temperature on the microorganisms' (Waksman et al. 1939); 'Evaluation of inoculums in composting' (Golueke et al. 1954); 'Rate of composting' (Wiley and Pearce 1955, Snell 1957); and 'Optimum moisture content and rate of oxygen consumption during composting' (Schulze 1960, 1962a) are still widely cited in the literature and books regarding composting. Many advances have been made in the field of sludge composting since the 1970s because of the demise of the open dump (Kuter 1995).

DETAILS ON COMPOSTING

Composting Substrates

A wide variety of organic wastes generated from different sources or combinations thereof can be used as compost substrates. The wastes should be free from uncompostable materials such as plastics, glass, metal objects and hazardous compounds in order to produce good quality compost. The major sources of organic wastes are the organic fraction of municipal solid wastes, park and yard wastes, market vegetable wastes, industrial wastes, agricultural wastes fecal sludge (Sarkar et al. 2016, Alamin and Bari 2022) and sewage sludge. The fundamental constituents of organic wastes are carbohydrates and sugar, fat, protein, hemicellulose, cellulose, lignin and ash (Waksman, 1939). The percentage of each constituent is different in different organic wastes. The easily biodegradable constituents are carbohydrates, sugar, fat and protein (de Bertoldi et al. 1983, Epstein 1997). These are present in higher percentages in food waste. Although hemicellulose, cellulose and lignin-enriched materials are less

ISBN: 978-984-35-4034-8

biodegradable (Snell 1957), they are often added with other wastes for proper adjustment of C/N ratio, moisture content and porosity. Examples of less biodegradable substrates are paper, straw and sawdust. The appropriate process technology, quality and subsequent utilization of compost considerably depend on the type and initial quality of the substrates.

Microorganisms

A large variety of microorganisms are responsible for composting. The microorganisms are abundant in air and soil as well as in the wastes to be composted. The odor emission from a garbage-containing bag after one or two days of storage represents the presence of these microorganisms and their decomposition activities in the wastes. Microorganisms can be classified into three main groups based on their temperature ranges for growth namely Psychrophili, Mesophilic and Thermophilic (Prescott et al. 1996). Various genera of bacteria, fungi, algae and protozoa belong to each group. The main microorganisms responsible for biological degradation in composting are bacteria, actinomycetes and fungi (Golueke 1977, Gonawala and Jardosh 2018) of mesophilic and thermophilic groups.

Composting Processes

Composting is the controlled biological decomposition of organic waste into a stable, pathogen-free end product. Although this biological decomposition can take place under aerobic or anaerobic conditions, composting is mainly considered as an aerobic process (Schulze 1960, Stentiford et al. 1985). Furthermore, most practiced and controlled composting processes are aerobic (Kulkarni 2017). Anaerobic composting is the digestion or fermentation of organic matter under anaerobic conditions (Tchobanoglous et al. 1993) and is generally applied for the production of biogas, mainly methane (de Bertoldi et al 1988, Diaz et al. 1993). The decomposition of organic wastes in composting can be described by the following equation and the physical appearance of the composting process can be illustrated in Figure 1:

$$\text{Organic Waste} + O_2 \xrightarrow{\text{Microorganisms}} \text{Compost} + CO_2 + H_2O + NH_3 + \text{Heat} + \text{Other minor compounds}$$

Composting biochemical equation

Figure 1 Physical appearance of process

As indicated in Equation, microorganisms decompose or oxidize the organic compounds to simple, stabilized end products, with the production of heat. During the process, oxygen is consumed and carbon dioxide, water, and often ammonia is released. The heat energy is partially used for cell synthesis of the microorganisms. However, the heat production is sufficient to raise the temperature up to the thermophilic range. The composting process can be explained in many ways. According to several researchers (Gray et al. 1971, Sarkar et al. 2016), the composting process can be divided into four phases as related to temperature, namely, (a) lag phase, (b) growth phase, (c) thermophilic phase, and (d) maturation phase.

Classification of Composting Systems

Various classifications of composting technologies are mentioned in different references including some additional terms such as mesophilic composting, thermophilic composting, vermicomposting, passively aerated composting, etc. However, the technologies are often classified into two broad groups, namely, open (non-reactor system) and closed (in-vessel or reactor system) systems (Haug 1993, de Bertoldi et al. 1985). Sometimes, a combination of these systems is also practiced. Mostly, the closed system is used for the initial high decomposition stage and after that maturation or curing takes place in the open system. Based on the above mentioned references a detailed classification of composting systems is presented in Figure 2 and each system is discussed in the following sections.

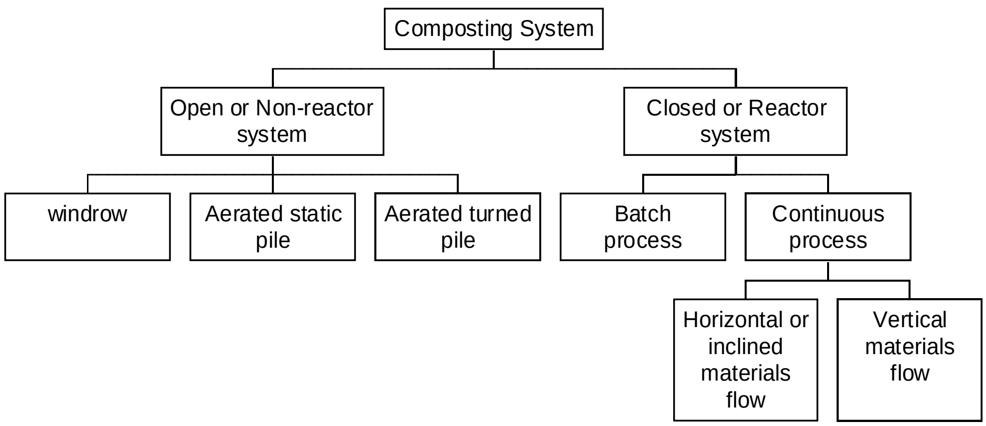

Figure 2 Detailed classification of composting systems (Bari1999).

a) Open or Non-reactor System

Open or non-reactor systems entail the formation of long windrows or piles from a composting substrate. The width and height of the piles range from 2 to 4.5 m and 1 to 2.5 m, respectively. The windrow or pile could be formed in an open field or under a shade. These systems are further classified as (i) windrow, (ii) aerated static pile (forced aeration) and (iii) aerated turned pile (forced aeration).

(ai) Windrow: In the turned windrow system, aeration is provided by mechanical turning and natural ventilation. Mobile equipment provides frequent turning during a composting period of several weeks. Turning also promotes uniform decomposition and sanitization of the end product. Due to the emission of offensive odors, long processing time, large area requirements, and other limitations, this system is not usually appropriate in urban areas except for yard wastes. Turned windrow systems need a long time to produce stable compost. Long processing times from four to eight months are common for open systems (Goldstein 1997).

(aii) Aerated static pile (forced aeration): In the aerated static pile system the composting piles are formed on a porous aeration base or air distribution system. The base includes a layer of wood chips or straw which are placed over perforated pipes. Usually, air blowers or fans are used for forced aeration. In upflow (positive pressure) aeration, the air is blown through the perforated pipes and then distributed through the aeration base. In downflow (negative pressure) aeration, the air is sucked from the pile via the aeration base. A layer of mature compost is used for covering the aerated composting pile to improve the insulation of the pile. Instead of forming windrows, some systems have been using rectangular cross-sectioned long open channels with concrete side walls and aeration base at the floor (Gies 1993).

(aiii) Aerated turned pile (forced aeration): In this system, rails or tracks are so installed on the top of the aeration base at the floor of rectangular cross-sectioned long open channels with concrete side walls, which a turning machine can move. It may overcome the problems associated with uneven settling of materials and excessive drying because water can be added during the turning operation (Manser and Keeling 1996).

b) Closed or Reactor System

ISBN: 978-984-35-4034-8

Closed or reactor systems are sophisticated methods in which composting is conducted within a fully closed system. High-quality compost, maximum composting efficiency and minimization of environmental nuisances are achievable if a proper controlling system is adopted. In practice, two to three weeks of composting time have been assigned for the initial high decomposition stage. However, most closed composting systems have a separate curing and storage step after the initial stage. Sometimes curing is also carried out in the reactor, though normally curing is performed in an open system. The closed system can be further classified into two processes, namely, (i) batch process and (ii) continuous process.

(bi) Batch process: The reactors used in the batch process are cubical or cylindrical in shape. Sometimes open-top reactors are also used. Usually, the height of these reactors is 2 to 2.5 m, and/or the diameter 2.5 to 3 m. Aeration is provided from the bottom of the reactor. The waste materials are re-mixed and re-moistured periodically. These are conducted either inside or outside using a mechanical agitator or a front-end loader, respectively. Some of the batch reactors may have the provision to rotate slowly or intermittently. Examples of this process are container, box and drum composter.

(bii) Continuous process: Different types of continuous processes have been developed. These can be classified as (a) horizontal and inclined material flow reactors and (b) vertical material flow reactors. In both types, the waste materials may remain under mixing or non-mixing condition, though they are continuously moving from one end to another or from top to bottom, respectively. Aeration is also provided from the bottom floor. One common example of horizontal and inclined material flow reactors is the tunnel reactor.

Factors Affecting the Composting Process

The rate of microbial activity or degradation in the composting mass depends on certain important physical and chemical factors which should be considered in the design and operation of a composting process. These factors are particle size, C/N ratio, water content, temperature, pH and aeration. During composting, the first five factors change with time whereas aeration supplies oxygen removes excess moisture and heat and thereby plays a key role in process control.

a) Particle Size and Porosity

The particle size of the substrate can vary depending on the physical nature of the waste materials. The particle size of composting materials should be as small as possible so as to allow for efficient aeration and to be easily decomposed by bacteria, fungi and actinomycetes (Jeris and Regan 1973, Gonawala and Jardosh 2018), because smaller particles have a greater surface-to-volume ratio. Thus, more surface area is available for microbial decomposition and subsequently, the composting efficiency is increased. Different types of screening or shredding machines are used, respectively, for sorting or cutting the substrate to get the required particle size. Usually, a sorting or cutting process is applied for municipal solid wastes and agricultural residue. Shredding is also applied for oversize bulky materials to make them suitable as structural support in the composting of sludge and livestock wastes.

b) C/N Ratio

The carbon to nitrogen (C/N) ratio is the most important indicator of the availability of nutrients for microbial use in composting. Nitrogen is the major nutrient required by microorganisms in the assimilation of carbon substrate from organic wastes. Phosphorus is next in importance while potassium, magnesium, sulfur, calcium and trace quantities of several other elements all play a part in cell metabolism (Skitt 1972). High C/N ratios inhibit the growth of microorganisms and thereby reduce the decomposition rate. At low C/N ratios, nitrogen could be lost as ammonia, especially in conditions of high temperature and forced aeration. Extremely high amounts of nitrogen in a composting mass can form enough ammonia to be toxic to the microbial population, further inhibiting the process (USEPA 1992). High or low C/N ratios can be adjusted by adding high nitrogen or carbon-rich wastes, respectively. Sawdust, wheat straw, grass clippings, dry leaves, etc. are examples of carbon-rich materials, whereas poultry manure, slaughterhouse waste, sewage sludge, etc. are nitrogen-rich. The C/N ratio decreases during the composting process as carbon are lost in the form of carbon dioxide.

c) Moisture Content

Moisture content (MC) is often termed water content (WC). Microorganisms need a certain amount of water for their metabolism and reproduction. Water is the key ingredient that transports substances within the composting mass and makes the nutrients physically and chemically accessible to the microorganisms (USEPA 1992). Biological activity is greatly reduced at substrate moisture contents below 40% (Epstein 1997). The upper limit of moisture content may vary from 55 to 85% depending on the structural strength of the materials in wet conditions and the availability of the pore space for proper aeration. Fibrous or bulky materials such as straw or wood chips can absorb relatively large quantities of water and still maintain their structural integrity and porosity (Haug 1993). According to Golueke (1977) the maximum permissible moisture content for straw and rice hulls is 75 to 85% and for municipal refuse and manure 55 to 65%.

d) pH

Considerable changes in pH value occur during the composting process. In the beginning, the formation of organic acids and carbon dioxide lowers the pH value to approximately 5 or less, whereas with process progress the pH value reaches up to 8 to 8.5 (USEPA 1992, Tchobanoglous et al. 1993). McKinley and Vestal (1985) proposed that the increase in pH may be an indirect indicator of high levels of microbial activity in composting.

e) Temperature

Temperature affects the composting process in several ways. The species and number of microorganisms change with increments in temperature. The decomposition rate and heat production are affected by these microorganisms. Due to the accumulation of heat, the temperature rises first to the mesophilic phase (25 to 45 °C) followed by the thermophilic phase (over 45 °C). After the thermophilic phase, the temperature again decreases to the mesophilic phase and finally to the ambient level. A typical temperature pattern is similar to that presented in Figure 3. Usually, the thermophilic temperature is attained after 1 to 4 days.

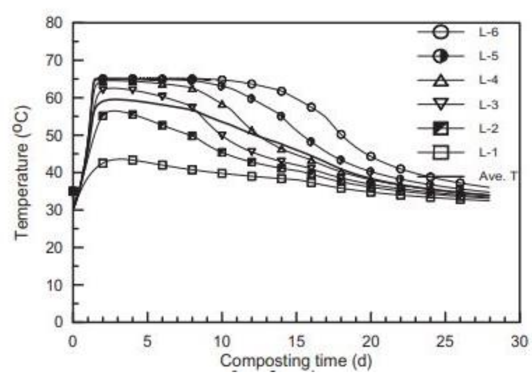

Figure 3 A typical temperature variation in a forced aeration composting mass

Hay and Kuchenrither (1990) reported that temperatures above 60 °C are common in large windrows and in certain instances the temperature stayed above 71 °C for several days. Maximum reported thermophilic temperatures were 74 °C for a pilot-scale reactor (VanderGheynst et al. 1997), 75 °C in a forced aerated composting pile (Willson 1983), 78 °C at the center of an aerated pile (Epstein et al. 1976), and 80 °C at the top layers of a pilot-scale pile (Bhamidimarri and Pandey 1996). Although there is some variation in the optimum temperature range due to variations in waste materials and operational practices, in most of cases it is reported as 55 to 60 °C. On the other hand, an acceptable level of pathogen destruction results when temperatures are maintained at 55 °C or above for 3 consecutive days (Burge et al. 1981, Golueke 1983). Thus, from the above discussion, the range of optimum temperature appears to be 55 to 60 °C.

f) Oxygen and Aeration

Aeration supplies oxygen to the microorganisms for aerobic biological degradation of organic wastes in the composting mass and is a key process control parameter of the forced aeration composting system (Atauzzaman and Bari 2020). Insufficient or mal-distributed aeration leads to the onset of anaerobic conditions, with a decrease in the rate of decomposition and evolution of offensive odor (Skitt 1972). Aeration requirements for biological degradation can be determined from the stoichiometric reaction of organic waste oxidation. As a process control parameter, the important application of aeration is to supply oxygen and to remove excess heat generated by microbial activity for maintaining the optimum temperature. The air supply needs for temperature and moisture control typically are ten or more times greater than those for biological decomposition, so that, when these needs are met, biological oxygen demands also will be safely satisfied (Kuter 1995).

Wiley and Pearce (1955) studied the effect of different aeration rates in continuously mixed reactors containing approximately 16 kg of garbage mixture with a moisture content of 52 to 58%. The effect of aeration was evaluated from the temperature curve during composting. Low aeration rates of 0.17 to 0.28 L/min/kg VS resulted in a late peak temperature. Medium aeration rates of 0.39 to 1.26 L/min/kg VS provided a peak temperature after four days and after that, the temperature declined slowly. High aeration rates of 1.41 to 3.35 L/min/kg VS also provided a peak temperature after four days but after that, the temperature declined rapidly. In another study on sludge composting it is suggested that an aeration rate of 0.30 to 0.83 L/min/kg dry solids, provided on an intermittent basis, results in oxygen levels from 5 to 15% throughout the pile.

Mathematical Models to Predict the Composting Factors

Different composting models are proposed and successfully applied in recent years. Using a developed mathematical model of the composting process, the effect of airflow rate on the above-described factors can easily be illustrated (Bari and Koenig, 2007, 2012). Mathematical formulations and theory had been reported for the degradation rate of organic waste (Schulze, 1960, Nakasaki et al., 1985), temperature dependency of reaction rate (Haug, 1993 Bari et al., 2000; David and Cesar, 2003), reaction order (Bari et al., 2000) and influence of the C: N ratio on the composting rate (Neugebauer et al. 2017).

PRODUCT STABILITY

The main objective of composting is to produce a biologically stable or mature and pathogen-free humus-like end product i. e. compost, which can be beneficially used as a soil conditioner or for other purposes. The biological stability or maturity of compost affects its successful utilization in agriculture. Compost with a very low decomposition rate, after a thermophilic phase where easily decomposable organic compounds are completely oxidized, can be described as stable or matured. If the compost is not sufficiently stabilized, it will cause subsequent problems in storage, transportation, utilization and in the final disposal site. Unstable compost emits an offensive odor and decreases plant growth due to the presence of phytotoxic substances (basically ammonia, ethylene oxide and organic acids, etc.). A number of physical, biological and chemical methods have been suggested and evaluated to measure the degree of stability of compost. Among those, the self-heating test, temperature decline, color and odor, microbial respiration, seed germination and plant growth, C/N ratio, pH and other chemical tests are significant

Self-heating Test

The self-heating test and its procedure were developed in Germany (LAGA 1985, BGK 1994 cited by Bari 1999). It is a simple test and an excellent indicator of biological stability if properly conducted (Koenig 1997), and does not require sophisticated equipment (Zimmerman 1991). Brinton et al. (1995) reported that the self-heating test integrates a number of factors present in normal composts such as temperature, aeration, etc. and therefore may provide data that correlate well with field observations about compost behavior. In the self-heating test, suitably prepared waste samples of optimally adjusted moisture content are loosely filled into Dewar bottles (volume = 1.5 L, inner diameter = 100 mm) open to the atmosphere. A temperature sensor is inserted for monitoring. The bottles are then kept at room temperature of approximately 23 ^oC. If the waste is not yet biologically stable, it will further degrade aerobically, generating heat that will cause a temperature rise. Usually, the maximum temperature T_{max} is reached after two to five days. The test ends after T_{max} is culminated and rapidly declining temperatures are observed, at the latest after ten days. T_{max} attained is used as an indicator of biological stability to define the stability index SI. The SI of waste is classified in degrees from I to V, in ascending order of biological stability, and ranges from raw, unstabilized waste (SI = I) to completely stabilized waste (SI = V). The temperature curves of typical self-heating tests for fresh compost (SI = I) and mature compost (SI = V) are shown in Figure 4, with T_{max}, A72 (area under the temperature curve after 72 hours) and I_{max} (maximum temperature increasing rate) indicated in the graph.

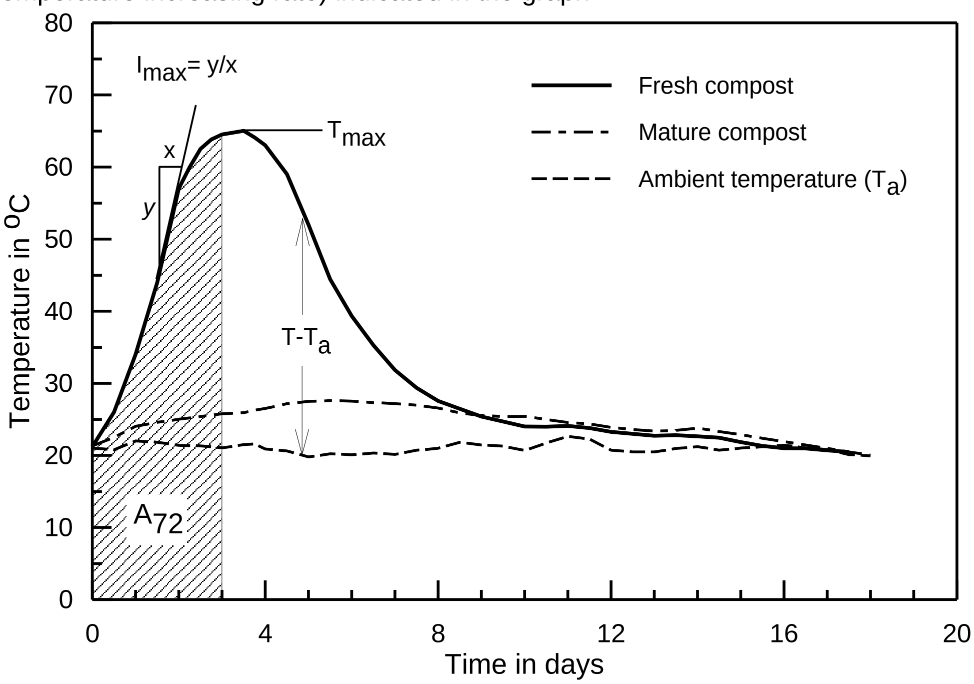

Figure 4 The temperature curve of a typical self-heating test for fresh compost, matured compost, T_{max}, A72 and I_{max} are shown.

T_{max} also corresponds approximately with the area under the temperature curve A72 (after 72 hours). Based on the result of the self-heating test, the biological stability of waste and compost can be classified as shown in Table 1 (LAGA 1985 Cited by Bari 1999).

Table 1. Classification of waste according to degree of biological stability

T_{max}, in °C	20-30	30-40	40-50	50-60	60-70	>70
I_{max}, in °C/h	<0.3	0.3-0.45	0.45-0.8	0.8-1.4	1.4-2.0	>2.0
A_{72}, in °C.h	<1700	1700-2000	2000-2500	2500-3000	3000-3500	>3500
RA[a] in mg O_2/g VS-h	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	>2.0	
Degree of biological stability (Stability index SI)	V stable, mature	IV	III ⟵	II ⟶	I	I Un-stable

I_{max} = maximum temperature increase; RA = respirometric activity; [a]Based on Iannotti et al. (1994) as cited by Epstein (1997)

Temperature Decline

The final drop in temperature after the thermophilic phase to or near ambient ±5 °C, may be considered as a measure of end product stability. Golueke (1977) stated that once the temperature has dropped to 40-45
°C, the material can be stored indefinitely without causing problems.

Color and Odor

The color of the final product after effective decomposition should be dark brown or almost black. Gray et al. (1973) reported that the product from farm and garden wastes is gray-black or brown-black in color. The brown color is one of the specifications of the final compost produced from wastewater sludge of some projects in the USA (USEPA 1992). Generally, the offensive odor of the waste material decreases during the first stages of decomposition and almost disappears by the end of the composting process. However, the evaluation of stability based on color and odor mostly depends on the experience of the operator.

C/N Ratio

The C/N ratio is often used as an index of compost maturity. Jimenez and Garcia (1992) noted that the C/N ratio is one of the most important parameters in the control of the composting process and in the determination of the degree of maturity of the newly formed organic materials. A high C/N ratio in immature compost causes nitrogen immobilization in the soil and affects plant growth. According to Inbar et al. (1990), a C/N ratio below 20 is indicative of an acceptable maturity in the final product, a ratio of 15 or even less is preferable. Garcia 1996). Viel et al. (1987) performed a composting test of a mixture of agricultural industrial waste and sawdust in a 100 L reactor. They showed that the C/N ratio of 34 to 35 in the initial mixture decreased to 20 to 22 after 120 days of composting. However, the final C/N depends on the initial composition of the waste to be composted.

pH

The pH is one of the indicators of the progress of the composting process. As mentioned previously, at the beginning of composting, the formation of organic acids and carbon dioxide lowers the pH value to approximately 5 or less, whereas with further progress the pH value reaches 8 to 8.5. The pH of the final product considerably depends on the type of initial waste mixture. The pH ranges reported for finished compost produced from municipal solid waste were 7.0 to 7.5 (Canet and Pomares 1995), for sewage sludge 5 to 9 (Kuter 1995), mixed garden waste compost 7.5 to 7.8 (Keeling et al. 1995), and for manures 5 to 6 (Gies 1995). However, for plant growth, pH levels between 5 and 8 are acceptable (Manser and Keeling 1996).

UTILIZATION OF COMPOST FOR DIFFERENT PURPOSES

Odor Removal

The emission of odor is an important concern in composting facilities. Biofilters have been used for the treatment of odors and volatile organic compounds in exhaust gases collected from wastewater treatment facilities and composting operations (Metcalf and Eddy 2004, Haug 1993). Biofiltration means that an odorous airflow is passing through a layer of filter material (compost, filamentous peat, etc.), followed by biodegradation of the captured odor components. It is reported that biofilters removed more than 99% H2S and 70% volatile organic compounds. More than 99% removal of various odorous compounds through biofilters are also reported (Sebastian 2013). Therefore, in most cases, the odor removal efficiency was found to be very high. The recommended design and operating parameters for biofilters are presented in Table 2.

Table 2. Recommended design and operating parameters for compost biofilter. Modified from Haug (1993)

Filter media	biologically stable compost, peat, granular activated carbon, soil
Media depth	1 - 1.5 m
Air distribution	uniform manifold with a base of rock
Moisture content	50 to 70%
pH	6.5 to 7.5
Temperature	near ambient, or 15 to 45 ^{o}C
Air loading rate	< 100 m^3/h-m^2, unless pilot testing supports higher loading
Air residence time	30 to 60 sec, unless pilot testing supports a shorter time

Other Usages

Beneficial uses of compost are increasing mainly in the following fields: in landscaping as a soil conditioner, in agriculture as an organic fertilizer and in horticulture as a growing media (Roy et al. 2013). The organic matter in the compost improves the physical properties of soil, including enhanced aggregation, increased soil aeration, lower bulk density, less surface crusting, increased moisture holding capacity and improved infiltration (Kuter 1995), which are necessary for crop production. Haug (1993) stated that compost contains valuable nutrients including nitrogen, phosphorus, and a variety of essential trace elements. It can improve the growth and vigor of crops in commercial agriculture and home-related uses. Manser and Keeling (1996) reported that compost, by improving soil structure, increases the ability of soil to resist erosion from water and wind. Application of compost in agricultural land increase water holding capacity (Faysal et al. 2015). Specific uses of compost include: (i) daily cover for landfills; (ii) top dressing on golf courses and lawns, land reclamation, and high-way shouldering (USEPA 1992); and (iii) media for biofilter. Compost is also used as a filtering media for treating stormwater runoff which carries pollutants such as sediments, solubilized metals, oil and grease, and nutrients (Conrad 1995).

SIGNIFICANCE

The popularity of composting has increased due to several environmental benefits such as:

- Fast conversion of the organic solid waste to a biologically matured end product

- In case of separate collection method, recovery of waste material in the form of compost for utilization in agriculture, horticulture, or other applications, as a soil conditioner, potting soil, organic fertilizer and landscaping material,
- effective hygienization of pathogenic bacteria present in the organic waste
- In case of mixed waste using mechanical and biological processes, stabilization and volume/moisture reduction of the waste materials prior to environmentally sound final disposal in landfills. Usually, there will be no long-term reactions in the landfill. There would be no disturbance due to animals.
- Comparatively cheap to costly methods are available. However, all composting processes are effective solid waste treatment methods depending on the duration of the operation.

CONCLUSIONS

- The main composting technologies are forced aeration, and mechanical turnover in a reactor or in a windrow composting pile. The reactors could be static or slowly rotating and the windrow could be formed in an open field or inside a shelter. Furthermore, the process could be batch or continuous.
- Mechanical biological process can be applied for the stabilization of the degradable organic part of the mixed municipal solid wastes before final sound disposal to landfills.
- The duration of composting could be eight weeks to twelve months depending on the process applied.

REFERENCES

Alamin M. and Q. H. Bari (2022). Extent of degradation in three stage co-composting of fecal sludge and solid waste, Journal of the Air & Waste Management Association, DOI: 10.1080/10962247.2022.2064936

Atauzzaman M. and Bari Q. H. (2020) Effect of passive and forced aeration on composting of market solid waste. International Journal of Engineering & Technology. Vol. 9(1):182-186. DOI: 10.14419/ijet.v9i1.30301

Bari, Q. H. (1999). Effect of Different Modes of Aeration on Composting of Solid Waste in a Closed System. Ph. D. Thesis, Department of Civil Engineering, The University of Hong Kong, Hong Kong.

Bari, Q.H., and Koenig, A. (2012). Application of a simplified mathematical model to estimate the effect of forced aeration on composting in a closed system. Waste Management, http://doi.org/10.1016/ j.wasman.2012.01.014, Elsevier, Vol. 32, pp. 2037 – 2045.

Bari, Q.H., Koenig, A., (2007). Composting in a closed system: effect of airflow rate on vertical temperature distribution. In: Haarstrick, A., Reichel, T. (Eds.), Landfill Modeling, IWWG Monograph Series. CISA Publisher, Padova, Italy, p. 11

Bari, Q.H., Koenig, A., Tao, G.H., (2000). Kinetic analysis of forced aeration composting- i. Reaction rates and temperature. Waste Management and Research, ISWA 18, 303–312

Bhamidimarri, S. M. R., and Pandey, S. P. (1996). Aerobic Thermophilic Composting of Piggery Solid Wastes. Water Science Technology, Vol. 33, No. 8, pp. 89-94

Brinton, W. F., Evans, E., Droffner, M. L., and Brinton, R. B. (1995). Standardized Test for Evaluation of Compost Self-Heating. BioCycle, No. 11, pp. 64-68.

Burge, W. D., Colacicco, D. and Cramer, W. N. (1981). Criteria for Achieving Pathogen Destruction During Composting, Journal of Water Pollution Control Federation, Vol. 53, No. 12, pp. 1683-1690.

Canet, R. and Pomares, F. (1995). Changes in Physical, Chemical and Physico-Chemical Parameters During the Composting of Municipal Solid Wastes in Tow plants in Valencia. Bioresource Technology, Vol. 51, pp. 259-264.

Conrad, P. (1995). Commercial Applications for Compost Biofilters. BioCycle, No. 10, pp. 57-60.

David and Taylor, Y (1993). The Compost Book. Robert Hale, London.

David, M.C., Cesar, V.S., (2003). Modeling temperature effects on decomposition. Journal of Environmental Engineering 129 (12), 1149–1156.

De Bertoldi, M. D., Vallini, G., Pera, A. and Zucconi, F. (1985). Technological Aspects of Composting Including Modeling and Microbiology. In Composting of Agricultural and Other Wastes, ed., Gasser, J. K. R., Elsevier Applied Science Publishers, London, pp. 27-41.

Epstein, E. (1997). The Science of Composting. Technomic Publishing Co. Inc., Lancaster.

Faysal S. W., Bari Q. H., Hossain M. and Ratul S. J. (2015) Effect of using compost on water holding capacity of soil. In: Proceedings of the WasteSafe 2015–4th International Conference on Solid Waste Management in Developing Countries; 15–17 February, Khulna, Bangladesh. Khulna University of Engineering and Technology; 2015. p. 176-180.

Garcia M., Otero D. and Mato S. (1996). New Bulking Agents for Composting Sewage Sludge (pteridium sp. and ulex sp.), a Laboratory Scale Evaluation. In The Science of Composting, (eds) Bertolid M. D., Sequi P., Lemmes B. and Papi T., Blackie Academic and Professional, an Imprint of Chapman & Hall, pp. 1170-1173.

Gies G. (1993). In-Vessel Composting of Food Scraps at the Ontario Science Center. BioCycle, pp. 72-75.

Gies, G. (1995). Composting Food Processing Residuals, Canadian Facilities. BioCycle, No. 8, pp. 36-39.

Goldstein, J. (1997). Monitoring Compost Process and Quality. BioCycle, Vol. 38, No. 7, pp. 48-49.

Golueke, C. G. (1977). Biological Reclamation of Solid Wastes, Rodale Press, Emmaus, PA, USA.

Golueke, C. G. (1983). Epidemiological Aspects of Sludge Handling and Management BioCycle, Vol. 24, No. 3-4, pp.50-59.

Golueke, C. G., Card, B. J. and McGauhey, P. H. (1954). A Critical Evaluation of Inoculums in Composting. Applied Microbiology, 2, pp. 45-53.

Gonawala S. S., Jardosh H. (2018) Organic waste in composting: a brief review. International Journal of Current Engineering and Technology. Vol. 8(1):36-38. DOI: 10.14741/ijcet.v8i01.10884.

Gray, K. R., Biddlestone, A. J. and Clark, R. (1973). A Review of Composting - Part 3, Process and Products. Process Biochemistry, Vol. 8, No. 10, pp. 11-30.

Gray, K. R., Sherman, K. and Biddlestone, A. J. (1971). A Review of Composting - Part 1. Process Biochemistry, Vol. 6, No. 6, pp. 32-36.

Haug, R. T. (1993). The Practical Handbook of Compost Engineering. Lewis publishers, Boca Raton.

Hay, J. C. and Kuchenrither, R. D. (1990) Fundamentals and Application of Windrow Composting. Journal of Environmental Engineering, Vol. 116, No. 4, pp. 746-763.

Iannotti, D. A., Grebus, M. E., Toth, B. L., Madden L. V. and Hoitink, H. A. J. (1994). Oxygen Respirometry to Asses Stability and Maturity of Composted Municipal Solid Waste. J. Environmental Quality, Vol. 23, pp. 1177-1183.

Inbar, Y., Chen, Y. and Hadar, Y. (1990). Humic Substances Formed During the Composting of Organic Matter. Soil Sci. Soc. Am. J., Vol. 54, pp. 1316-1323.

Ishola T. M. and Ishola E. T. (2019) Composting and sustainable development. Encyclopedia of Sustainability in Higher Education. Pp. 1–8. DOI: 10.1007/978-3-319-63951-2_122-1

Jeris, J. S. and Regan, R. W. (1973). Controlling Environmental Parameters for Optimum Composting, Part I. Compost Science, Vol. 14, No. 1, pp. 10-15.

Jimenez, E. I. and Garcia, V. P. (1992). Determination of Maturity Indices for City Refuse Composts. Agriculture, Ecosystems and Environment, 38, pp. 331-343.

Keeling, A. A., Griffiths, B. S., Ritz, K., and Myers, M. (1995). Effects of Compost Stability on Plant Growth, Microbiological Parameters and Nitrogen Availability in Media Containing Mixed Garden Waste Compost. Bioresource Technology, 54, pp. 279-284.

Koenig, A. (1997). The Self-Heating Test: A Simple Method to Determine Biological Stability of Dewatered Digested Sewage Sludge. In Proceedings of 6th IAWQ Asia-pacific Regional Conference, Seoul, Korea, May 20-23, Vol. 1, pp 544-551.

Kulkarni S. J. (2017) Aerobic composting - a short review. International Journal of Research & Review. Vol. 4(2):73-75.

Kuter, G. A. (1995). Biosolids Composting. A Special Publication, Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994 USA.

Manser, A. G. R. and Keeling, A. A. (1996). Practical Handbook of Processing and Recycling Municipal Waste. Lewis Publishers, Boca Raton.

Mantell, C. L. (1975). Composting. In Solid Wastes: Origin, Collection, Processing, and Disposal, John Wiley & Sons, Ch II.10, pp. 223-243.

Metcalf & Eddy (2004). Wastewater Engineering, Treatment, Disposal and Reuse. McGraw-hill Book Company.

Nakasaki, K., Sasaki, M., Soda, M. and Kubota, H. (1985). Effect of Seeding During Thermophilic Composting of Sewage Sludge. Applied and Environmental Microbiology, Vol. 49, No. 3, pp. 724-726.

Neugebauer M, Sołowiej P, Piechocki J, Czekała W, Janczak D. (2017) The influence of the C: N ratio on the composting rate. International Journal of Smart Grid and Clean Energy. Vol. 6(1):54-60. DOI: 10.12720/sgce.6.1.54-60

Prescott, L. M., Harley, J. P. and Klein, D. A. (1996). Microbiology. Wm. C. Brown Publishers, Boston, 3re ed, pp. 127-130.

Roy T. K., Rahman S. and Dev P. K. (2013) Compost fertilizer from municipal solid wastes and its application in urban agro-forestry nurseries: a case study on Khulna city. Journal of Bangladesh Institute of Planners.;6:191-199.

Sarkar S, Pal S, Chanda S. (2016) Optimization of a vegetable waste composting process with a significant thermophilic phase. Procedia Environmental Sciences. Vol. 35:435–440. DOI: 10.1016/j.proenv.2016.07.026

Sarkar S., Pal S., and Chanda S. (2016) Optimization of a vegetable waste composting process with a significant thermophilic phase. Procedia Environmental Sciences. No 35:435-440. DOI: 10.1016/j.proenv.2016.07.026

Schulze, K. L. (1960). Rate of Oxygen Consumption and Respiratory Quotients During the Aerobic Decomposition of a Synthetic Garbage. Compost Science, Spring, pp. 36-40.

Schulze, K. L. (1962). Continuous Thermophilic Composting. Applied Microbiology, 10, No. 2, pp. 108-122.

Sebastian V. V. E., Goen, H. Goen, Wipa Charles and Ralf C. R. (2013) Design and Development of a Novel Biofilter. In the 5th IWA Odour and Air Emissions Conference Jointly Held With 10th Conference on Biofiltration for Air Pollution Control at: San Francisco. DOI: 10.13140/2.1.2827.1368

Skitt, J. (1972). Composting. In Disposal of Refuse and Other Waste, Charles Knight & Co. Ltd., London, pp. 87-105.

Snell, J. R. (1957). Some Engineering Aspects of High-Rate Composting. J. Sanitary Engineering Division, ASCE Paper 1178.

Spellman, F. R. (1997). Wastewater Biosolids to Compost. Technomic Publishing Co. Inc., Lancaster.

Stentiford, E. I., Mara, D. D. and Taylor, P. L. (1985). Forced Aeration Co-composting of Domestic Refuse and Sewage Sludge in Static Piles. In Composting of Agricultural and Other Wastes, ed., Gasser, J. K. R., Elsevier Applied Science Publishers, London, pp. 42-55.

Taiwo A. M. (2011) Composting as a sustainable waste management technique in developing countries. Journal of Environmental Science and Technology.Vol. ;4(2):93-102. DOI: 10.3923/jest.2011.93.102

Tchobanoglous, G., Theisen, H., and Vigil, S. (1993): Integrated Solid Waste Management, Engineering Principles and management Issues. McGraw-hill Book Company, N. Y., USA.

USEPA (1992) Composting Yard and Municipal Solid Waste. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Technomic Publishing Company, Inc., P. A., USA.

VanderGheynst, J. S., Gossett, J. M. and Walker, L. P. (1997) High-Solid Aerobic Decomposition: Pilot-Scale Reactor Development and Experimentation. Process Biochemistry, Vol. 32, No. 5, pp. 361-375.

Viel, M., Sayag, D. and Andre, L. (1987) Optimization of Agricultural Industrial Wastes Management Through In-vessel Composting. In Compost: Production Quality and Use, Eds. Bertoldi, M. D. et al., Elsevier Applied Science, London, pp. 130-137.

Waksman, S. A., Cordon, T. C., and Hulpoi N. (1939), Influence of Temperature upon the Microbiological Population and Decomposition Processes in Composts of Stable Manure. Soil Science, 47, 83-113.

Wiley, J. S. and Pearce, G. W. (1955) A Preliminary Study of High-rate Composting. In Proceedings, American Society of Civil Engineers, New York, Vol. 81, Paper No. 846, pp. 1-28.

Willson, G. B. (1983) Forced Aeration Composting. Water Science and Technology, Vol. 15, pp. 169-180.